Improving Properties of Concrete by Replacing Cement Partially With Silica Fume

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***Abstract*— In the modern world with the acute necessity for the developing infrastructure facilities such as development of roads, bridges, buildings etc. consumption of cement abnormally leads highly to the depletion of natural resources like lime, gypsum and other materials. The efforts have been made to replace cement with any other suitable material. It is an attempt to reduce the use of cement by replacing silica fume with cement in the concrete. This study is an experiment in the nature of silica fume and its influences on the properties of fresh concrete. First the strength parameters of concrete without any parts replacement were studied then strength parameters by partial replacement with silica fume have been studied by placing cubes and a cylinder on compression testing machine (CTM). The industries are facing problems for proper disposal of their byproducts. This study resolves two issues, one is the proper disposal problem and the other one is reducing the cement content. The replacement of cement with silica fume was from 0 to 20% at an increment of 5% for the cubes and cylinders. From results it is observed that partial replacement of cement with silica fume having significant effect on the compressive strength of the cube and the split tensile strength cylinder. The strength of concrete increases rapidly as we increase the silica fume content and the optimum value of compressive strength is obtained at 15% replacement. After 15% of replacement the results start decreasing under uniform load condition of 4kN and similarly the split tensile strength increases up to 15% and then start decreasing under the uniform load condition of 2kN.**

***Index Terms*— Silica Flume, cement, CTM, Compressive Strength.**

I. INTRODUCTION

Leaving the waste materials to the environment directly can cause environmental problem. Hence the reuse of waste material from Industries has been emphasized. Industrial wastes can be utilized for production of new products or can be used as admixtures. So that natural resources are used more effectively and the environment is protected from waste. These industrial wastes are dumped in the nearby land and the natural fertility of the soil is spoiled.

The American Concrete Institute, defines silica fume "as a by-product of the manufacturing of elementary, silicone or silicone-containing alloys" as "extremely thin some, crystalline silica produated in electric arc furnaces." Typically it is a gray rock, a little like asphalt in Portland or fly ash. The figure demonstrates a typical silica fumes as They emerge from a furnace

Silica fume is also known as micro silica or condensed silica fume, which is used as an artificial

pozzlanic admixture. It is a material which resulting from reduction of quartz with coal in an electric arc. Furnace in the manufacture of silicon or ferrosilicon alloy. Chemical composition of silica fume contains more than 90% silicon dioxide, other constituents are carbon, sulphur and oxides of aluminum, iron, calcium, magnesium, sodium and potassium. The physical composition of Silica fume Diameter is about 0.1 micron to 0.2 microns, Surface area about 30,000 m^2/kg and Density varies from 150 to 700 kg/m^3.

Other names are frequently referred to as silica fume. This is the name of some other silica fumes

- Smoking condensed silica
- Micro-silk.
- Silica volatilized

II. METHODOLOGY

At the preliminary stage we have collected fine aggregates, cement, coarse aggregates, and silica

fine. We have completed fineness test, Standard consistency test, setting time, soundness and Compressive strength test on OPC 53 grade cement and silica fume which have given The satisfactory results. The consistency test on cement have been also completed so as To get W/C ratio and fineness test on aggregates have been also carried out.

We have also done compressive test, workability test, which will be require for concrete Mix design.

The collection of Silica Fume will also be carried out and depending upon its suitability we Are planning to replace it with Cement.

After the all test and material collecting have been completed next is the mix design to Get proper proportion of concrete ingredients for casting of concrete, we will be casting Concrete blocks using silica fume along with conventional Concrete material at the suitable ratios and with this the newly formed concrete shall be Tested for strength

A. MATERIAL TESTING

The physical properties of concrete material play vital role in deciding their suitability Whether to be used or not in the manufacturing of concrete. They also decide the durability Of the concrete. The experimental values which we get from the test conducted on concrete Materials such as cement, sand and aggregates are compared with the values of IS standards So these comparison decides the suitability of concrete material

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TEST CONDUCTED ON CEMENT

1. Fineness test on Cement (IS: 4031-1968):

In this test the 100gm of sample is weighed and taken on a standard IS Sieve No. 9 (90 Microns). Break down the air-set lumps in the sample with fingers. Continuously sieve the Sample for 10 to 15 min.

2. Standard Consistency test (IS: 4031-1968):

For finding out initial setting time, final setting time and soundness of cement, and strength A parameter known as standard consistency has to be used.

3. Setting time of cement (IS: 4031-1968):

Setting is the change of cement paste from a plastic stage to a stiff solid state. In this test We are taking in to account both initial setting time of cement and final setting time of Cement.The initial setting time of cement paste is defined as the time period between the time water Is added to cement and time of standard needle (1mm) fails to penetrate in the test block by 5mm-7mm from the bottom of the mould.

4. Soundness test on cement (IS: 4031-1968):

It is very important that the cement after setting shall not undergo any appreciable change Of volume. Certain cements have been found to undergo a large expansion after setting Causing disruption of the set and hardened mass. This will cause serious difficulties for the Durability of structures when such cement is used.

5. Compressive Strength Test (IS: 4031-1988, 2000, Part-4): The compressive strength of hardened cement is the most important of all the properties.Therefore, it is not surprising that the cement is always tested for its strength at the Laboratory before the cement is used in important work

TABLE I Tests on cement

Sr. No.	Type of Test	Obtained Value	Standard Value (IS: 12269-1987)
1	Fineness Test	3.7%	Not more than 10%
2	Standard Consistency%	34	Should not be more than 10% of weight
3	Initial Setting Time	36 min	Should Not be less than 30 Min
4	Final Setting Time	430 min	Should Not be more than 600 Min
5	Soundness Test	2 mm	Not More than 10 mm
6	Compressive Strength Test	54.3 N/mm²	33 to 53 N/mm²

TEST CONDUCTED FINE AGGREGATES

1. Specific Gravity (IS: 2386-1963 Part – 3): In concrete technology, specific gravity of fine aggregates is use in design calculations of Concrete mixes. Specific gravity of aggregate is also required in calculating the compacting Factor in connection with the workability measurements

2. Water Absorption:

Water absorption plays a vital role in W/C ratio of concrete, water cement ratio depends Upon the porosity of fine aggregates, and more water absorption will affect both workability And durability of concrete.

3. Moisture Content:

Free moisture in both coarse aggregate and fine aggregate affects the quality of concrete in More than one way. In case of weigh batching, determination of free moisture content of The aggregate is necessary and then correction of water/cement ratio to be effected in this Regard

4. Fineness Modulus (FM.) (2386-1963, Part – 3): Fine aggregates are graded depending on a parameter known as Fineness Modulus.

TABLE II Tests on cement

Sr. No.	Type of Test	Experimental Value	Standard Value
1	Specific Gravity	2.8	2.6-2.8
2	Water absorption	0.6%	0.1-2%
3	Moisture Content	0.4%	Up to 1%
4	Fineness Modulus	3.840	2.2-2.9

B. TESTS CONDUCTED ON COARSE AGGREGATES

1. Specific Gravity (IS: 2386-1963 Part – 3):
2. Water Absorption:
3. Moisture Content:
4. Fineness Modulus (FM.) (2386-1963, Part – 3):
3. Impact Value Test (IS: 2386-1963, Part-4):

A test designed to evaluate the toughness of stones i.e. resistance of stones to fracture under Repeated impacts may be called an impact test for road stones.

4. Crushing Value Teat (IS: 2386-1963, Part-4): The strength of coarse aggregates is assessed by aggregates crushing test. The aggregate Crushing value provides a relative measure of resistance to crushing under gradually applied Compressive load. To achieve a high

quality of pavement, aggregate possessing low Aggregate crushing value should be preferred

Generally the structure are having two type of loads such as static load &dynamic load. These loads are mainly effects on the structure during case of earthquake. For the calculation of the load on silo wall IS 4995:(Part I) 1974 General Requirement and Assessment of bin Load, should be used. Janssen"s theory is used for the calculation of the horizontal pressure on silo walls due to stored material & Vertical pressure on the horizontal cross section of the stored material. The various loads on part of silo structure are as follows

TABLE IV Test on Coarse aggregates

Sr. No.	Type of Test	Experimental Value	Standard Value
1	Specific Gravity	2.73	2.6-2.8
2	Water Absorption	0.45%	0.1-2%
3	Moisture Content	0.25%	Up to 1%
4	Fineness Modulus	3.064	3.2-3.9
5	Impact Value Test	1.05%.	Not exceed 30%
6	Crushing Value Test	8.48%	Not exceed 30%

PROPERTIES OF SILICA FUME

- Chemical properties of silica fume:
- Amorphous
- Silicon dioxide>85%
- Trace elements depending upon type of fume
- Physical properties of silica fume:

- Particle size (typical) < 1μm
- Bulk density:(as produced): 130 to 430densit (densified): 480 to 720 kg/m^3
- Specific gravity: 2.2
- Specific surface: 15,000 to 30,000 m^2/kg

CONCRETE MIX DESIGN (M25 GRADE):

The main aim of mix design is to enable a concrete technologist to design a concrete mix For a particular strength. Mix designed can be defined as The process of selecting suitable Ingredients of concrete and determining their relative proportions with the object of Producing concrete as economically as possible which has a certain minimum properties, Notably, strength, workability and durability.

Water cement ratio w/c = 0.45 Water content = 197.4 kg/m3

Cement content = (197.4/0.44) = 448.6 kg/m3 Volume of all in aggregate = 1 – [{448.6/(3.15 x 1000)} + (197.4/1000)] = 0.660 m3

A reduction of 0.05 in w/c will entail and increase of coarse Aggregate fraction by 0.01.

Coarse aggregate fraction = 0.558 +.01 =.568 Volume of fine aggregate = 1 – 0.568 = 0.432 Mass of coarse aggregate = 0.660 x 0.568 x 2.84 x 1000 = 1064.65 kg/m3 Mass of fine aggregate = 0.660 x 0.432 x 2.64 X 1000 = 752.71 kg/m3

Cement = 358.9 kg/m3 Water = 197.4 kg/m3

Fine Aggregates = 821 kg/m3 Coarse Aggregate = 1070.75 kg/m3

1 Mix Design for Cube

M25 = 1:1:2

2 For cube with 0% silica fume Total volume of 1 cube = 8 kg Total cube = 9

Total volume = 9 x 8 = 72 kg Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg „ Weight of Cement = 18 kg

Weight of Water 0.45 x 18 kg = 6.75 kg

3 For cubes with 5% silica fume

Total volume 1 cube = 8kg Total cubes = 9

Total volume = 72 kg Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg Weight of Cement = 0.95 x 18 = 17.1 kg

Weight of Silica fume = 0.05 x 18 = 900 gm Weight of Water = 0.45 x 18 = 6.75 kg

4 For cube with 10% silica fume Total volume of 1 cube = 8 kg Total cube = 9

Total volume = 9 x 8 = 72 kg Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg „ Weight of Cement = 0.90 x 18 = 16.2 kg

Weight of Silica fumes = 0.10 x 18 kg = 1.8 kg Weight of Water 0.45 x 18 kg = 6.75 kg

5 For cube with 15% silica fume Total volume of 1 cube = 8 kg Total cube = 9

Total volume = 9 x 8 = 72 kg Weight of Sand = 18 kg

Weight of Coarse aggregate = 36 kg „ Weight of Cement = 0.85 x 18 kg =16.2 kg

Weight of Silica fume = 0.15 x 18 kg = 2.7 kg Weight of Water 0.45 x 18 kg = 6.75 kg

III. TEST ON CONCRETE

WORKABILITY BY SLUMP CONE TEST (IS: 1199-1959):

Workability is that property of fresh concrete which determines the ease and homogeneity With which concrete

can be mixed, placed, compacted and finished. The slump cone test Indicates the behavior of concrete cone under the action of gravitational force.

TABLE V
Test on Slump

Replacement Level%	Slump (mm)	Compaction Factor
0%	49	0.81
5%	52	0.82
10%	56	0.91
15%	58	0.92

COMPRESSIVE STRENGTH OF CONCRETE

There mix proportion was 1:1:2 (M-25), the water/cement Ratio was kept as 0.5. Three cubes of each sample were Prepared and cured for 7 days and 28 days.

TABLE VI
Compressive strength after 7 days for cube

Sr. No.	Mix Description	Failure Load (KN)	Compressive Strength (N/mm2)	Average Compressive Strength (N/mm²)
1	0% S.F. + 100% Cement	249 353.2 379.8	11.11 15.7 16.88	**14.6**
2	5% S.F. + 95% Cement	430 640 590	32.44 32.44 30.66	**31.87**
3	10% S.F. + 90% Cement	540 400 500	28.88 23.55 24	**24.2**
4	15% S.F. + 85% Cement	470 420 440	28 24.8 26.44	**26.46**

TABLE VII
Compressive strength after 28 days for cube

Sr. No.	Mix Descriptio n	Failure Load(KN)	Compr essive Strength (N/mm2)	Average Compressive Strength (N/mm²)
1	0% S.F. +100% Cement	582.75 571.5 614.25	25.9 25.4 27.3	**26.2**
2	5% S.F. +95% Cement	684 724.5 713	30.4 32.2 31.7	**31.44**
3	10% S.F. + 90% Cement	35.4 33.16 36.2	35.4 33.19 36.2	**34.93**
4	15% S.F. + 85% Cement	643.5 711 684	28.4 31.6 30.4	**30.2**

A.3 FLEXURAL STRENGTH TEST ON CONCRETE

TABLE VIII
Flexural strength test result

	Flexural strength After 7 Days (N/mm²)	Flexural strength After 14 Days (N/mm²)
0% of Slilica Fume	4.80	5.5
5% of Silica Fume	5.11	6.07
10% of Silica Fume	7.10	8
15% of Silica Fume	7.33	8.5

SPLIT TENSILE STRENGTH TEST

TABLE IX
Split tensile strength test result

	Flexural strength After 7 Days (N/mm²)	Flexural strength After 14 Days (N/mm²)
0% of Slilica Fume	3.20	4.47
5% of Silica Fume	3.70	4.65
10% of Silica Fume	4.15	4.90
15% of Silica Fume	3.85	4.70

IV. CONCLUSIONS

• In this research an experimental study has been conducted on Concrete by varying the percentage of silica fume as 0%, 5%,10% and 15% respectively to study the increase in the Compressive strength of concrete.

• Based on the experimental Investigation, the compressive strength was found to Increase at 10% addition of silica fume in the concrete. The Compressive strength was found to gradually decrease after 10% addition in the concrete.

After performing

II. the test and Analyzing their result, the following conclusions have been Derived: The results achieved from the existing study shows that Silica fume is great potential for the utilization in concrete as Replacement of cement.

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